ADMINISTRATIVE INFORMATION

1. **Project Name:** Development of Materials Resistant to Metal Dusting Degradation

2. **Lead Organization:** Argonne National Laboratory
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5. **Date Project Initiated:** Date Project Initiated: May 1, 2004

6. **Expected Completion Date:** April 30, 2007

PROJECT RATIONALE AND STRATEGY

7. **Project Objective:** The project goal is to mitigate degradation of metallic materials (used in structural applications) by developing new alloys that are resistant to metal dusting attack and with adequate strength properties for use in various process industry sectors at temperatures up to 800°C. Another goal is to engineer the surfaces of currently available metallic structural alloys (which have adequate mechanical properties) to resist metal dusting degradation.

8. **Technical Barrier(s) Being Addressed:** The lack of understanding of the mechanisms for the initiation and propagation of metal dusting attack is the major reason for the substantial commitments shown by the industrial sector that include process industries, alloy manufacturers, and end users. We believe that recent work conducted at Argonne National Laboratory has established the mechanisms for initiation of metal dusting in a variety of iron- and nickel-base alloys and the time is ripe to make significant advances in materials and surface-barrier development. The effort proposed in this proposal cannot be done by a single company as the companies have been concentrating their effort on mitigation by S addition (which is not practical in process systems that use Ni-base catalysts), by surface coatings produced at very high temperatures (a niche approach, not practical for several of the process components such as vessels, piping, etc.), on welding joints, etc. In addition, the lack of correlation between laboratory data and field data (within a given company and between companies) and the proprietary nature of the developed data has not been helpful in formulating an unified approach with the sponsorship of process industry, alloy manufacturers, and end users.

9. **Project Pathway:** The proposed project will develop alternate structural alloys with improved corrosion resistance and with adequate mechanical properties at temperatures up to 816°C (1500°F) and by surface modification of currently available structural alloys to mitigate metal dusting degradation. The project will involve design and construction of a high-pressure test facility for the exposure of candidate alloys and surface-engineered alloys to metal dusting environments that

simulate the temperatures, pressures, and chemistry prevalent in hydrogen and ammonia reformers and in syngas systems.

10. **Critical Technical Metrics:** The success in the project will be determined by the following criteria:
    - Development of alloys with adequate resistance to pitting attack up to 600°C.
    - Development of alloys with adequate mechanical properties and adequate resistance to metal dusting up to 700°C.
    - Development of alloys/claddings with metal dusting resistance up to 800°C.
    - Surface engineering approach to metal dusting resistance up to 800°C.

PROJECT PLANS AND PROGRESS

11. **Past Accomplishments:** Not applicable, project initiated in FY04.

12. **Future Plans:**

    - Procure materials, fabricate specimens, and perform metal dusting experiments with off-the shelf Ni-base alloys in simulated reformer effluent gas chemistry at temperatures in the range 450-700°C, using the existing test facilities.
    - Develop and fabricate alternate alloys with adequate mechanical strength properties and prepare specimens for exposure in metal dusting experiments.
    - Develop surface engineered specimens of Ni-base alloys by procedures such alumina, chromia, and/or silica surface layers and evaluate their susceptibility to coking, carbon deposition, and metal dusting attack in simulated reformer effluent chemistry at atmospheric and high pressures.
    - Perform mechanical tests (tensile and creep-rupture) on alternate alloys before and after exposure in metal dusting environments and establish the strength and microstructural properties of the materials.
    - Expose selected newly developed alloys and surface engineered materials in several locations in pilot and/or production systems (such as hydrogen reformers and syngas systems) in which metal dusting is a key degradation issue.

13. **Project Changes:** None

14. **Commercialization Potential, Plans, and Activities:** The materials developed under this project will have broad applications in the chemical, petrochemical, petroleum, steel, heat-treat industry sectors of the economy. A gradual implementation of new/modified materials is envisioned in U.S. plants for hydrogen production, and ammonia and methanol reformers, and in refinery environments over the time period of 2007-2025. MTI with member affiliates and with other avenues will disseminate the information to the technical communities at large and accelerate the implementation of the results in practice.

15. **Patents, Publications, Presentations:** None to date from the current project. Several journal publications, topical and final reports were issued from a prior project on metal dusting. A few relevant ones are listed below.
    - K. Natesan, Z. Zeng, V. A. Maroni, W. K. Soppet, and D. L. Rink, Metal dusting Research at Argonne National Laboratory, International Workshop on Metal dusting, Sep. 26-28, 2001.
    - Z. Zeng, K. Natesan, V. A. Maroni, Study of Metal Dusting Mechanism in Iron Using Raman Spectroscopy and X-ray Differection, International Workshop on Metal dusting, Sep. 26-28, 2001.

- V. A. Maroni, Applications of Molecular Spectroscopy Methods to the study of Metal Dusting Corrosion, International Workshop on Metal dusting, Sep. 26-28, 2001.
- K. Natesan, Z. Zeng, V. A. Maroni, W. K. Soppet, and D. L. Rink, Metaldusting Behavior of Coatings, International Workshop on Metal dusting, Sep. 26-28, 2001.
- K. Natesan, A. Purohit, D. L. Rink, and W. Salot, Analysis of Metal Dusting in a Waste Heat Boiler, International Workshop on Metal dusting, Sep. 26-28, 2001.
- K. Natesan et al., Study of Metal Dusting Phenomenon and Development of Materials Resistant to Metal Dusting: Annual Report, Argonne National Laboratory Report, ANL-02/05, February 2002.
- Z. Zeng, K. Natesan, Metal Dusting Mechanism of Fe and Ni Base Alloys, ASM International Materials Solutions Conference, Indianapolis, USA, November 5-8, 2001.
- Z. Zeng, K. Natesan, V. A. Maroni, Investigation of Metal Dusting Mechanism in Iron Using Raman Spectroscopy, X-ray Diffraction, and Electron Microscopy, Oxidation of Metal, 58, 147, 2002.
- Z. Zeng, K. Natesan, A New Mechanism for the Catalytic Growth of Carbon Filaments and Metal Dusting Phenomenon, Mat. Res. Soc. Symp. Proc. 755, DD5.1, 2002.
- Z. Zeng, K. Natesan, Relationship of Carbon Crystallization to the Metal Dusting Mechanism of Nickel, Chemistry of Materials, 15, 872, 2003.
- Z. Zeng, K. Natesan, and M. Grimsditch, Effect of phase compositions of oxide scale on metal dusting corrosion of Fe-base alloys, Corrosion, to be published.
- Proceedings of International Workshop on Metal Dusting, Sept. 26-28, 2001, ed. K. Natesan, Argonne National Laboratory.